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Geotechnical control of a major railway project involving tunnel works in Hong Kong

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ABSTRACT: This paper describes the role of the Geotechnical Engineering Office, Civil Engineering and Development Department of the Hong Kong Special Administration Region (HKSAR) Government in exercising geotechnical control for a major railway project in Hong Kong. It highlights the geotechnical aspects of the tunnel works and how the geotechnical control process protects public safety and adds value by ensuring an adequate standard of design, site supervision and risk management is applied. The successful implementation of best geotechnical risk management practice in the project is strongly influenced by the commitment of the project client to follow the core element of the Joint Code of Practice for Risk Management of Tunnelling Works and to follow up on the results of the independent auditing under the geotechnical control process.

1 INTRODUCTION

1.1 *Project description*

The Kowloon Canton Railway Corporation's (KCRC) Kowloon Southern Link (KSL) Project links West Rail's Nam Cheong Station and East Rail's East Tsim Sha Tsui (ETST) Station in the HKSAR. The 3.8 km long railway will have one new station, West Kowloon (WKN) Station.

The civil construction works of the project were packaged into three Design and Build contracts. The total project cost, including railway systems, is expected to be about HK$8.3 billion. The project is scheduled for completion in late 2009. The details of the three contracts are described below.

1.2 *Contract KDB200*

Contract KDB200 involves the section between ETST Station and Jordan Road via the former Marine Police Headquarters. WKN Station, two railway tunnels and two emergency vertical shafts, namely Canton Road Emergency Access Point (CREAP) and Peking Road Emergency Egress Point (PREEP), were included in this contract (see Figure 1 below). The contract was awarded to Link 200 JV (formally known as the Leighton – Balfour Beatty – Kumagai – John Holland Joint Venture).

Figure 1. Aerial photograph showing the alignment of Contract KDB200.

Figure 2. Slurry-type tunnel boring machine.

The geological sequence along the alignment generally comprises the following principal geotechnical units:

- fill (generally a few metres thick but up to 20 m thick at the West Kowloon Reclamation site);
- marine deposits and alluvium (described as clayey/silty sand and sandy silt/clay with some gravel, mainly found along Salisbury Road but also present locally near Haiphong Road and undredged pockets at the WKN Station);
- residual soil and saprolite, mainly completely to highly decomposed granite; and
- moderately decomposed to fresh medium-grained granite.

At the preliminary design stage, a cut-and-cover option was planned for the tunnels. However, KCRC decided to employ a Tunnel Boring Machine (TBM) for the twin railway tunnels between the launching shaft at the southern tip of WKN Station and the retrieval shaft at Salisbury Road to minimize potential disruption to road users, pedestrians, business operations and residents in the area. The twin railway tunnels are approximately 8 m in diameter and 1.1 km in length. The depth to tunnel crown varies from 8 m to 24 m.

The slurry-type TBM (see Figure 2) uses 3800 kilowatts of electricity, which is equivalent to over 5000 horsepower. It was design in Germany and its components were manufactured in Germany and China and finally assembled in Guangzhou. The 50 steel cutting discs enable the TBM to cut through 1.5 m of rock in about 40 minutes.

Notwithstanding the use of TBM, some works such as ground investigation and grouting were required under the contract on the already very busy road surface. Such works are to provide additional data for geotechnical design and to mitigate the impacts before construction of the relevant tunnel works sections.

The excavation for WKN Station was supported by diaphragm walls, while that for the remaining cut and cover tunnels was supported by temporary walls comprising sheet piles, pipe piles and struts.

The most challenging part of these works from a geotechnical perspective is the provision of a retrieval shaft outside the Sheraton Hotel in Salisbury Road serving as a works portal for the retrieval operation of the TBM. Traffic diversions were unavoidable. This part of the works was constructed using the cut-and-cover method. Temporary road decking has been erected to facilitate the underground works and to shorten the construction period.

1.3 *Contracts KDB300 and KDB400*

Contracts KDB300 and KDB400 involve the section between Jordan Road and Nam Cheong Station of the KCRC's existing West Rail (WR). The two contracts are divided at the Yau Ma Tei Ventilation Building (YMTVB) (see Figure 3). The tunnel lengths are 0.85 km and 1.06 km respectively. These contracts were awarded to China State Construction Engineering (Hong Kong) Limited.

In view of the ground conditions (mainly fill, marine deposits, alluvium and completely decomposed granite), the depth of the tunnel (about 20 m to soffit) and the lack of constraints on the ground surface, the cut-and-cover tunnel method has been adopted as the most suitable method in terms of time and cost for the majority of the tunnel length. The exception is the tunnel beneath Cherry Street, which would be constructed using a mined tunnelling method. The cut and cover excavation was supported by temporary walls comprising sheet piles, pipe piles, diaphragm walls, bored pile walls and struts.

The tunnel alignment is very close to many existing buildings, structures and utility services. Some are very sensitive to construction-induced ground movements such as the operating Mass Transit Railway tracks and buildings, highway bridge structures, Drainage Services Department structures (e.g. box culverts) and nearby buildings (e.g. the HSBC Centre). In order to monitor the effects of the construction on the surrounding buildings, structures and utility services, extensive geotechnical instrumentation

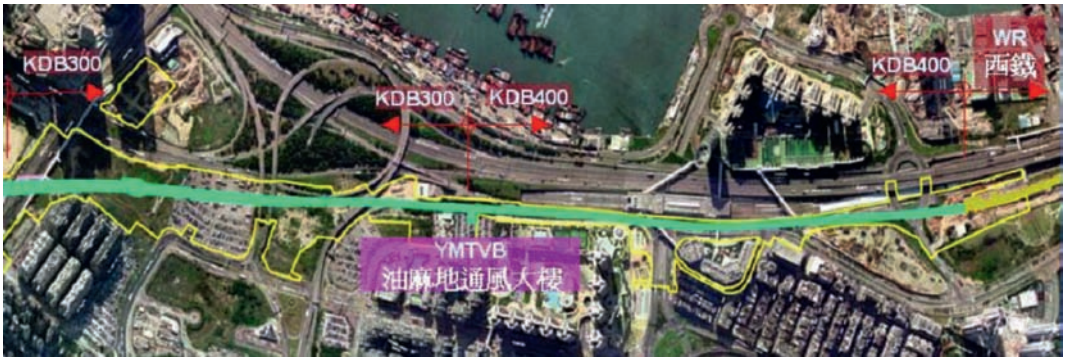

Figure 3. Aerial photograph showing the alignment of Contracts KDB300 and KDB400.

has been installed, including ground/ structure/utility settlement checkpoints, inclinometers, extensometers, tiltmeters, vibration monitoring checkpoints, standpipes and piezometers. Instrument readings are monitored against alert, action and alarm values as defined individually for particular instruments and sensitive receivers.

2 THE ROLE OF THE GEOTECHNICAL ENGINEERING OFFICE

2.1 *Buildings ordinance and regulations*

In the HKSAR, the regulatory control of building works, in the interest of protecting public safety, is by application of the Buildings Ordinance and Regulations (BOR). Under the BOR the definition of a "building" includes, inter alia, "…any underground space adapted or constructed for occupation or use for any purpose including its associated access tunnels and shafts". Therefore, the development of private underground space such as tunnels or caverns including their planning, design and construction all fall under the BOR.

A KCRC project is considered a private project in which the tunnel works may be exempted from the administrative procedures of approval and consent under the Buildings Ordinance. Under certain conditions, an Instrument of Exemption (IoE) would be prepared and issued by the Building Authority (BA) of the HKSAR Government. For the KSL Project, because of the significant risk to life and property, the design, risk management, construction and site supervision would need to be implemented to a good standard to protect public safety. Auditing of the standard of geotechnical design, site supervision and risk management is carried out by the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department, as a technical adviser to the Buildings Department (BD) of the HKSAR Government.

2.2 *Technical standards*

GEO has issued a technical guidance note TGN24 (GEO 2005a), on specific aspects of site investigation for tunnel works in the HKSAR. It supplements guidance on site investigation given in Geoguide 2 (GEO 1987) and Geoguide 4 (GEO 1992). The technical guidance note was prepared with the benefit of the experience gained from the Harbour Area Treatment Scheme Stage I (Pang et al 2006, Massey et al 2007).

GEO has also issued TGN25 (GEO 2005b), on the implementation of geotechnical risk management in relation to tunnel works. Tunnel works are defined as tunnels, shafts, caverns and associated underground facilities, however constructed. Construction of tunnel works may involve use of drill and blast methods, tunnel-boring machines, cut and cover methods, techniques that incorporate insitu ground treatment, groundwater control, installation of temporary and permanent supports, etc.

The relevant Government departments and the profession were consulted in the preparation of these guidance notes.

3 GEOTECHNICAL CONTROL PROCESS

3.1 *Instrument of exemption*

Within GEO a review panel has been set up to agree on the geotechnical auditing requirements to be included into the IoE, examine the key geotechnical aspects of major submissions related to tunnel construction for the project, and to oversee the standard of auditing. The input started right from the planning stage of the project in which KCRC demonstrated to GEO that they had adequately identified and assessed the geotechnical risks, and had taken suitable risk mitigation and control actions to manage the risks. In addition, KCRC committed to adopt the Joint Code of Practice (ABI & BTS 2004). The risks identified for the TBM tunnels related to plant procurement, manufacture of

segmental linings, delay in launch shaft availability, break-in to retrieval shaft, TBM assembly/removal and operation including encountering adverse ground conditions, unforeseen underground obstructions, causing excessive settlements or even damage to nearby buildings/structures/utilities during TBM operation and interventions, compressed air blow-out along areas of low soil cover and crossing over the operating MTR tunnels.

In early 2005, KCRC's consultants submitted preliminary scheme designs for auditing by BD/GEO, including a Geotechnical Basis of Design Report, Ground Movement Prediction Report, Geotechnical Instrumentation Report and an Existing Buildings and Structures Report, supported by a Geotechnical Data Report.

The BA issued the IoE to the KSL construction works on 30 July 2005 pursuant to the Kowloon Canton Railway Corporation Ordinance. The exemption is confined to only those procedures and requirements relating to approval of plans, consent to commencement and resumption of works and occupation of buildings provided under the BOR, such that the BA's duties and sanctioning powers to ensure standards of health and safety are not undermined.

Guidelines which KCRC were required to follow for making submissions to GEO for geotechnical works, including tunnel works, under the KSL project were agreed and included into the IoE and summarized in a Management Plan (KCRC 2005).

Under the agreement, KCRC had submitted the design statements and various method statements for the TBM tunnels, the cut and cover tunnels, CREAP, PREEP, the launching shaft and the retrieval shaft to BD/GEO for consultation.

KCRC had also submitted the excavation and lateral support (ELS) plans for the TBM tunnels where there is excavation, loading/unloading of the ground or changes to the groundwater regime. The critical parameters shown in the TBM ELS plans include the operating slurry pressures, the planned interventions (use of free air or compressed air depends on the anticipated ground conditions) and the air pressures where compressed air interventions are planned.

3.2 *Other requirements for KCRC under the IoE*

Under the IoE, KCRC is required to appoint Authorized Persons (AP), Registered Structural Engineers (RSE) and Registered Geotechnical Engineers (RGE) to co-ordinate the works and to certify the plans and documents as well as completion of the works; and to appoint Registered General Building Contractors (RGBC), and Registered Specialist Contractors (RSC) in the case of specialized railway construction works, to supervise and carry out the relevant works.

KCRC is also required to instigate an assurance system and control scheme to ensure that management of the construction works is at a standard not inferior to that required under the BOR. KCRC also employed a team of Resident Site Staff (RSS), led by a Construction Manager to act as the Engineer's Representative, to supervise the works and the implementation of the Project Risk Management Plan (KCRC 2006). In addition, AP, RSE, RGE, RGBC and RSC have jointly prepared Site Supervision Plans (SSP) in accordance with the Codes of Practice for Site Supervision (BD 2005a, b).

The Contractors were also required to appoint Independent Checking Engineers (ICE) to provide certification of consultation documents and verify geotechnical design submissions for both permanent and temporary works prior to forwarding to KCRC for review under the contracts.

KCRC ensure that submissions are made at all stages to BD, and to GEO where geotechnical aspects are involved, in a timely manner prior to the commencement of elements of the construction works through the AP/RSE/RGE. KCRC and the AP/RSE/RGE are required to ensure that all comments given by BD and other relevant parties, in connection with their submitted consultation documents, have been resolved to the satisfaction of BD and the party concerned prior to commencement of construction of the relevant part of the works.

3.3 *During construction*

During the course of works, the AP/RSE/RGE are required to keep on site copies of certified working plans, inspection and test records and other relevant reports for regular audit inspections by BD and GEO. When significant changes in design or method of working are necessary, then KCRC through the AP/RSE/RGE are required to report this to BD and GEO and ensure that all comments given by BD and GEO are resolved to the satisfaction of BD.

KCRC through the AP/RSE/RGE are required to report the following to BD and GEO immediately when the following circumstances arise:

- Construction accidents causing nuisance to the public.
- Irregularities causing inconvenience to the public and/or damage to nearby property.
- Construction non-conformities.

Since award of the first contract for the KSL Project in August 2005, monthly Buildings Ordinance Management Committee (BOMC) Meetings have been held by KCRC with representatives from KCRC Management, the AP/RSE/RGE and from Government including BD and GEO. One of the items of discussion is the scope, standard and timing of the geotechnical submissions from the RGE to GEO. Geotechnical auditing of the KSL Project is currently in progress.

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